

ABSTRACT

ORSER-SSEL Technical Report 20-74

INTERPRETATION OF PENNSYLVANIA AGRICULTURAL LAND USE FROM ERTS-1 DATA  
G. W. Petersen and A. D. Wilson

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7.7-1011.1  
CR-149284

LANDSAT-1 images from Southeastern Pennsylvania were interpreted

for the dates of January, April, July, and October. Various features were delineated on the ERTS imagery using bands 5 and 7 in this temporal analysis. These features were large in size and general in nature (i.e., agricultural lands, forests).

To study the complex agricultural patterns in Pennsylvania, a portion of an ERTS scene was selected for detailed analysis. Various photographic products were made and were found to be only of limited value. This necessitated the digital processing of the ERTS data. Using an unsupervised classification procedure, it was possible to delineate the following categories:

- a. forest land with northern aspect;
- b. forest land with a southern aspect;
- c. valley trees;
- d. wheat;
- e. corn;
- f. alfalfa, grass, pasture;
- g. disturbed land;
- h. built-up area;
- i. strip mines; and
- j. water.

Original photography may be purchased from:  
EROS Data Center  
10th and Dakota Avenue  
Sioux Falls, SD 57198

These land use categories were delineated at a scale of approximately 1:20,000 on the line printer output. Land use delineations were also made using the General Electric IMAGE 100 interactive analysis system. Recommendations were made to interface the digital processing capabilities of a large computer facility with an interactive analysis system such as the IMAGE 100.

(E77-10111) INTERPRETATION OF PENNSYLVANIA  
AGRICULTURAL LAND USE FROM ERTS-1 DATA  
Interim Report (Pennsylvania State Univ.)  
25 p HC A02/MF A01  
CSCL 05B  
G3/43 00111  
Unclas  
N77-18525

Interim Report

ORSER-SSEL Technical Report 20-74

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ERTS Investigation 082  
Contract Number NAS 5-23133

INTERDISCIPLINARY APPLICATION AND INTERPRETATION OF ERTS DATA  
WITHIN THE SUSQUEHANNA RIVER BASIN

Resource Inventory, Land Use, and Pollution

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Date: December 1974

## INTERPRETATION OF PENNSYLVANIA AGRICULTURAL LAND USE FROM ERTS-1 DATA

Gary W. Petersen and A. D. Wilson

Pennsylvania is located in the northeastern United States on the northern end of the Appalachian Mountains. The state is generally characterized by ridges and valleys in the southeastern one-half and by dissected plateau in the northwestern one-half. Most of the geologic materials of the state are of a sedimentary nature (Figure 1). The geology has been very important in shaping the land forms within Pennsylvania allowing the state to be divided into various physiographic provinces (Figure 2). Generally, each physiographic province has a uniquely different terrain with its associated land uses.

### INTRODUCTION TO PENNSYLVANIA AGRICULTURE

The agricultural areas of Pennsylvania are very closely associated to the geology, with most of the cropland located on limestone valleys of the Valley and Ridge Province. The limestones of the valleys weather into a very fertile soil, whereas the ridges are generally steeply sloping sandstone that weathers into an infertile soil. Hence, most of the ridges in this Province tend to be forested. Most of the soils that develop from shales in this Province also are relatively fertile and are usually in active agriculture. Another fairly important agricultural area is in the Piedmont Province in the extreme northeastern part of Pennsylvania. This is an area of gently rolling topography, and fertile soils.

Agricultural activity is less prominent in the Plateau Province. Much of the geology is flat-lying sandstones and shales that have been deeply dissected by erosion. The steep slopes, along with the infertile soils that have developed from these geologic materials, are forested and not conducive to good agriculture. Most of the strip mining operations for bituminous coal occurs in these flat-lying sediments, whereas most anthracite mining occurs in the folded sediments of the Ridge and Valley Province. Much of the northwestern and northeastern portions of Pennsylvania have been glaciated and are in active agriculture. The glacial process brought in fresh geologic materials which have since weathered into good agricultural soils.

The climate of Pennsylvania is humid temperate, which is similar to much of the midwest. This is shown in Figure 3, which indicates the tentative average date of the first flowers of the Persian lilac--a measure of phenological changes, or the advance of the spring. However, Pennsylvania differs from many states in its great elevational differences, with resultant effects on climate and vegetation. These effects are shown in Figure 4, where the phenological changes in the state are related to physiography and elevation.

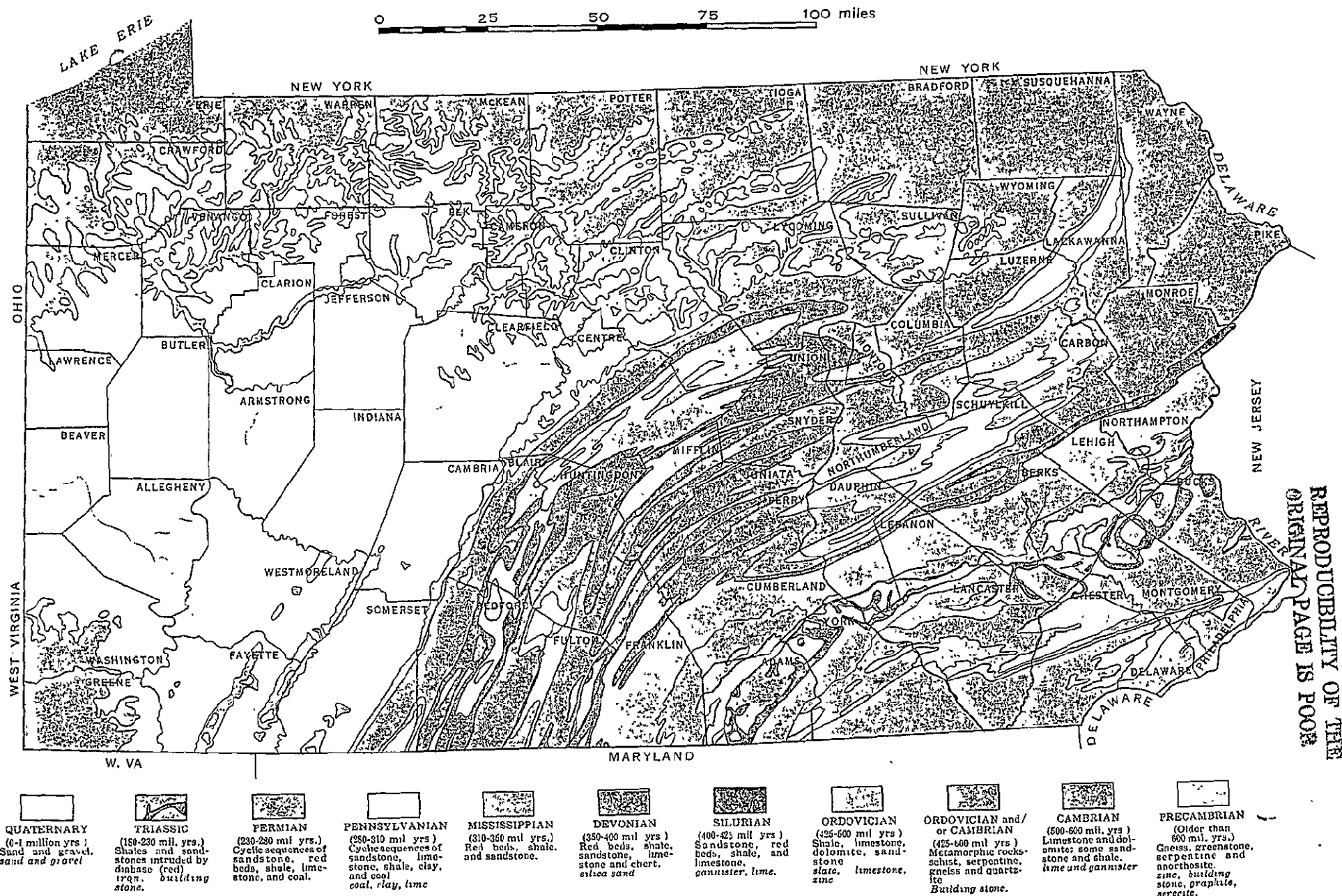


Figure 1: Geologic map of Pennsylvania. (Provided by the Pennsylvania Topographic and Geologic Survey.)

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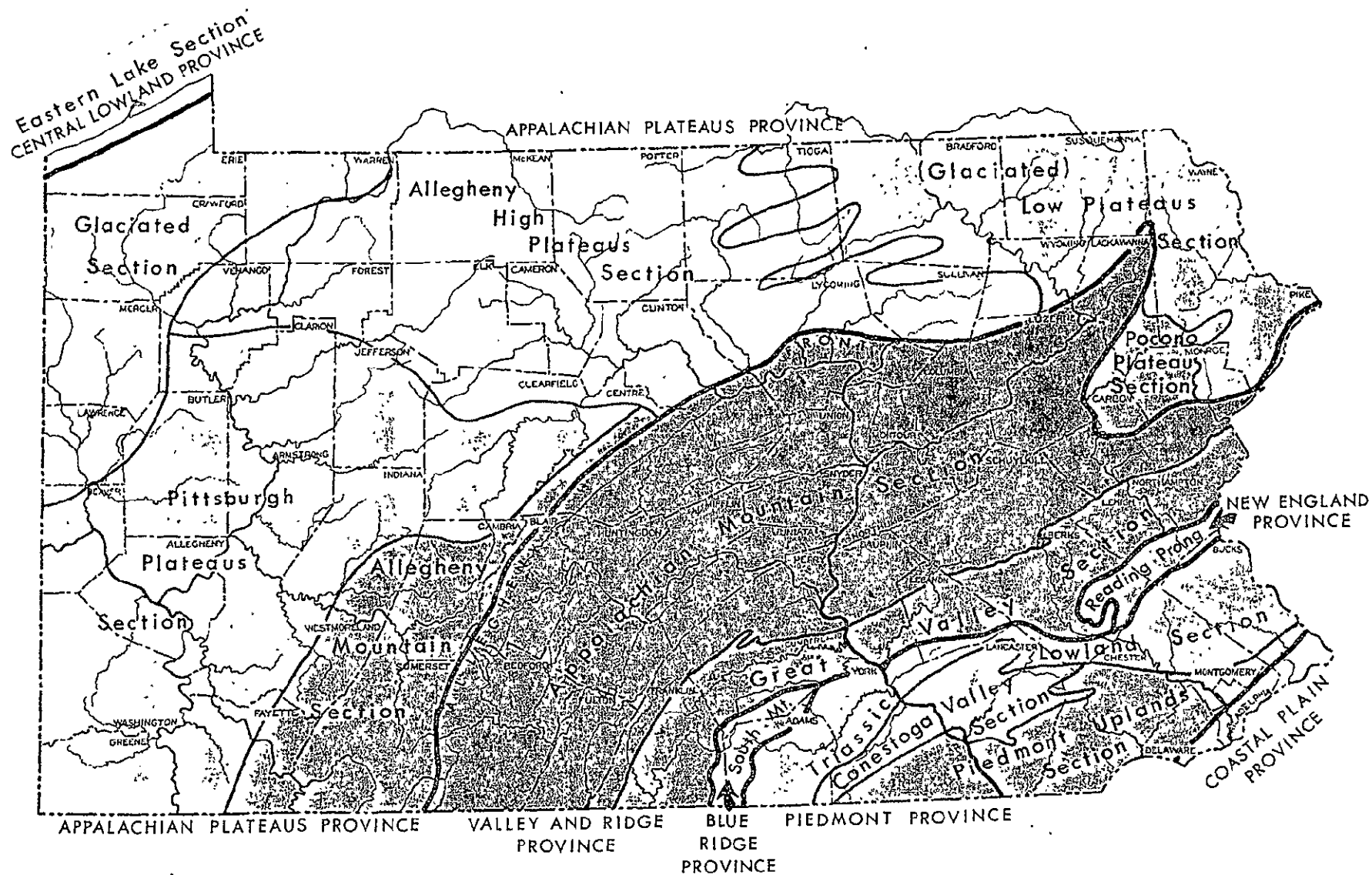


Figure 2: Physiographic provinces of Pennsylvania. (Provided by the Pennsylvania Topographic and Geologic Survey.)

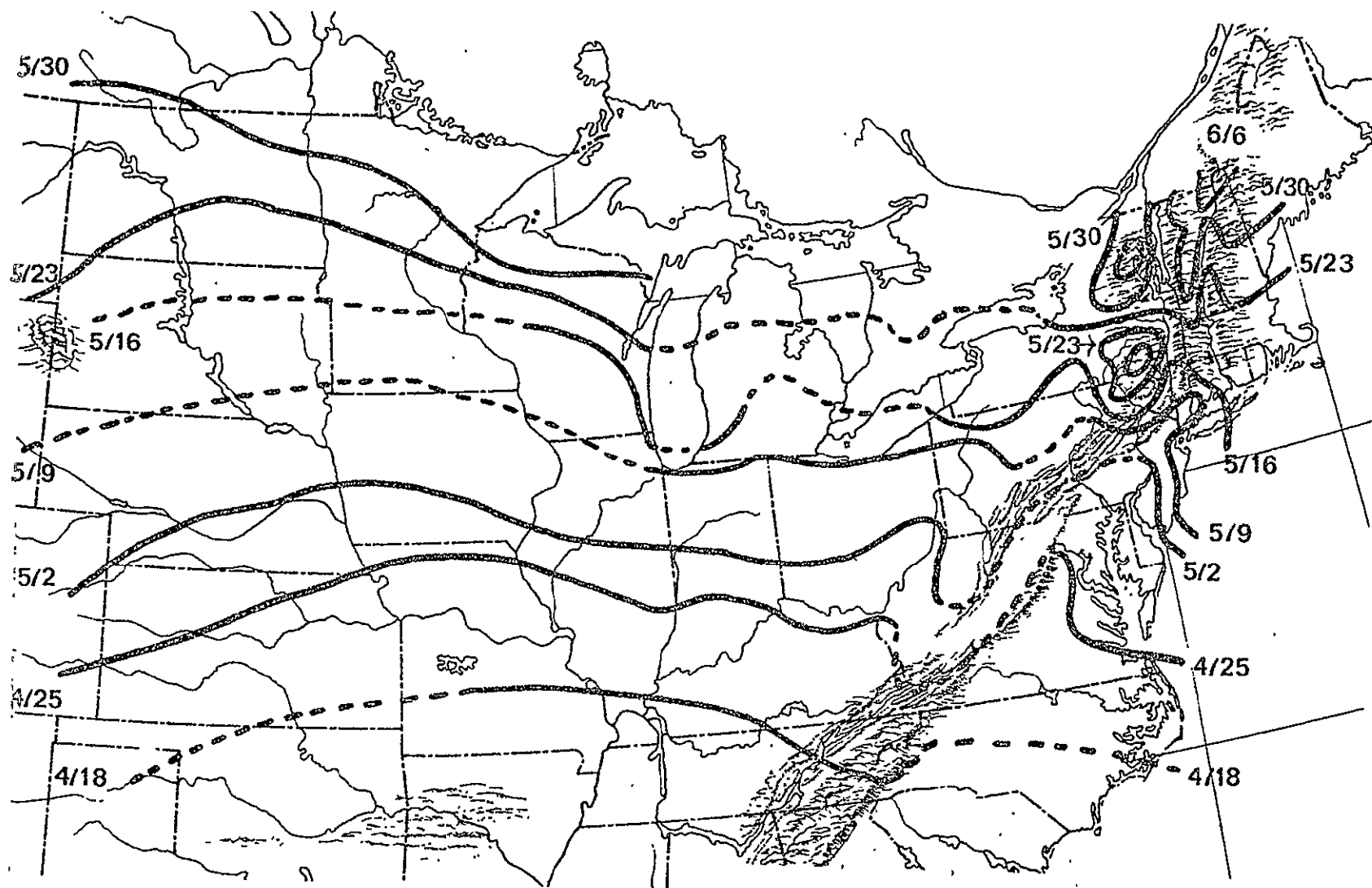


Figure 3: Tentative average dates of the first flowers of the Persian lilac in northeastern United States.

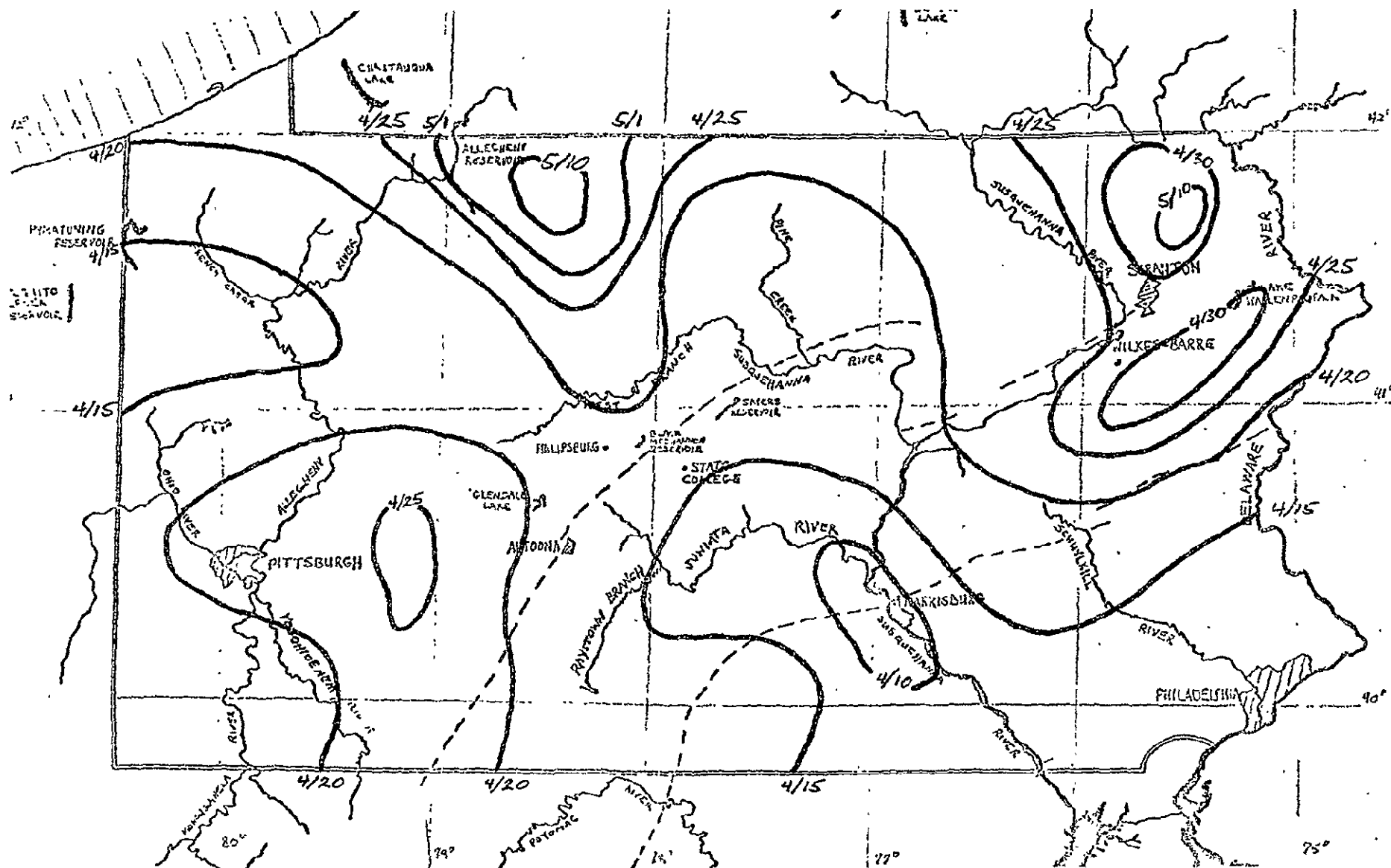


Figure 4: Tentative average dates of the first flowers of the Persian lilac in Pennsylvania.

The budding of the Persian lilac is almost a month later in the northern than in the southeastern portion of the state. The actual growing season varies within the state from approximately 70 to more than 220 days. Hence, when an average planting date is given for a crop, it should be planted two weeks earlier than that date in the southeastern Pennsylvania and two weeks later than that date in the north central part of the state.

Pennsylvania is primarily a forage crop state, with most of the agricultural crops grown as feed for livestock. A considerable portion of the agricultural land is in pasture. The major crop types, along with their average yields, planting dates and harvest dates, are given in Table 1. Potatoes and tobacco are grown to a minor extent.

Table 1. Major Crop Types In Pennsylvania

Crop	Approximate Acreage	Average Yield	Planting Date	Harvest Date
Hay (grasses & legumes)	2,000,000	2.3 tons/acre (4-6 tons/acre for alfalfa)	North latitudes: April 15, with companion crop. South latitudes: September 15.	Jun 15
Corn	1,500,000	78 bu/acre	May 15	Oct 15
Oats	375,000	47 bu/acre	Apr 15	Aug 1
Wheat (winter-soft red)	264,000	28 bu/acre	Sep 15	Jul 15
Barley (winter)	155,000	44 bu/acre	Sep 15	Jul 1
Soybeans	55,000	26 bu/acre	Jun 1	Sep 15

#### GENERAL OVERVIEW OF PENNSYLVANIA USING ERTS IMAGERY

Pennsylvania, at least by western standards, is not a large state. Most of the state can be mosaiced using six ERTS images.

Gross features stand out very well in the ERTS imagery. It is easy to locate the major rivers, cities, and strip mines. Most physiographic provinces can be delineated, especially the Piedmont, Valley and Ridge, and the Plateau Provinces. Portions of two of these provinces are covered by the ERTS scene outlined in Figure 5. Major agricultural areas can generally be delineated within an ERTS image, as can be seen from Figures 6 through 13. This is best illustrated in band five of the July and October images (Figures 10 and 12), where the forested areas show up as dark tones in contrast to the lighter tones of the agricultural valleys. It is also possible to delineate highways, especially, when they cut through forested areas. With



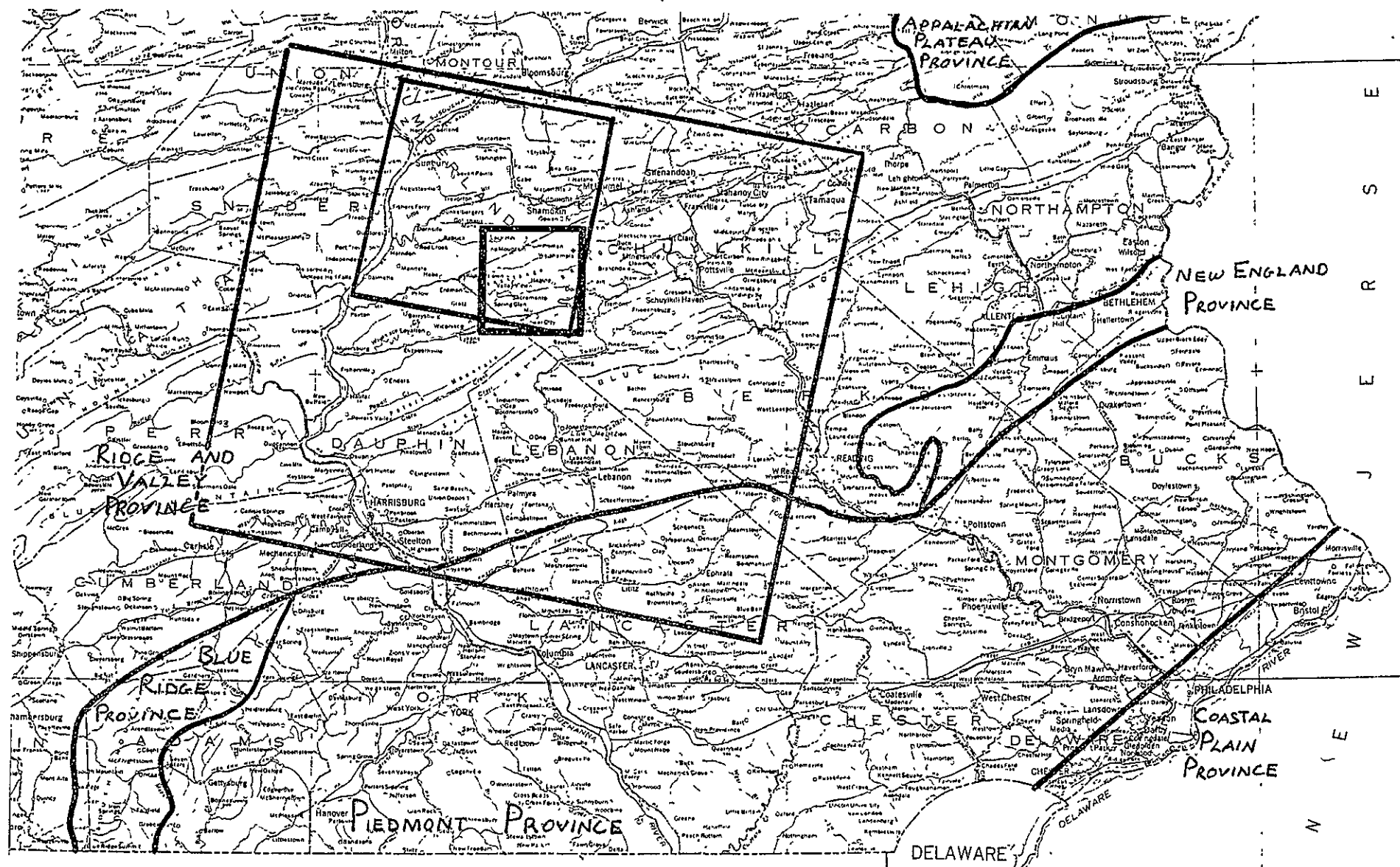


Figure 5: Location map for study site (medium sized square), the ERTS scenes shown in Figures 6 through 13 (large square), and the U2 scene shown in Figure 14 (small square). Physiographic provinces are also shown.

Figures 6 through 9: Seasonal ERTS scenes in Channel 5.

Figure 6: Winter ERTS scene in Channel 5.  
(Scene 1170-15191, 9 January 1973.)

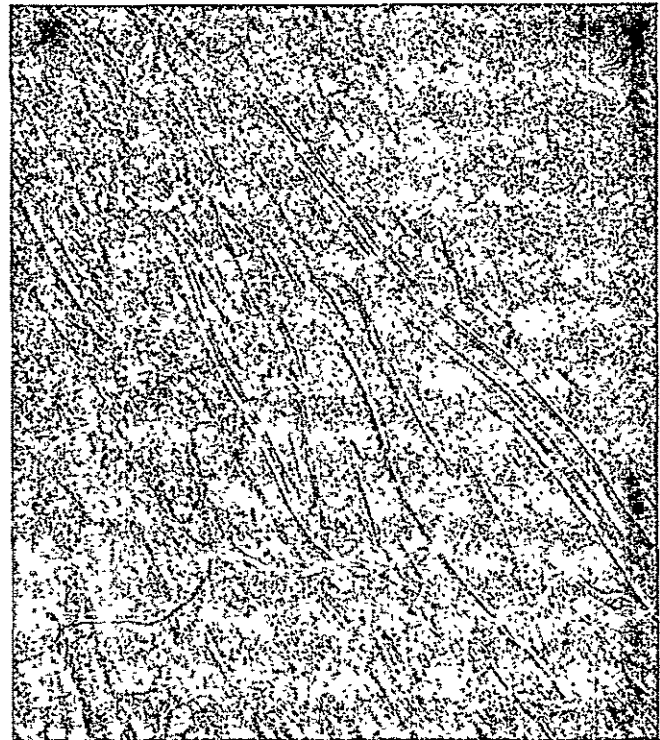
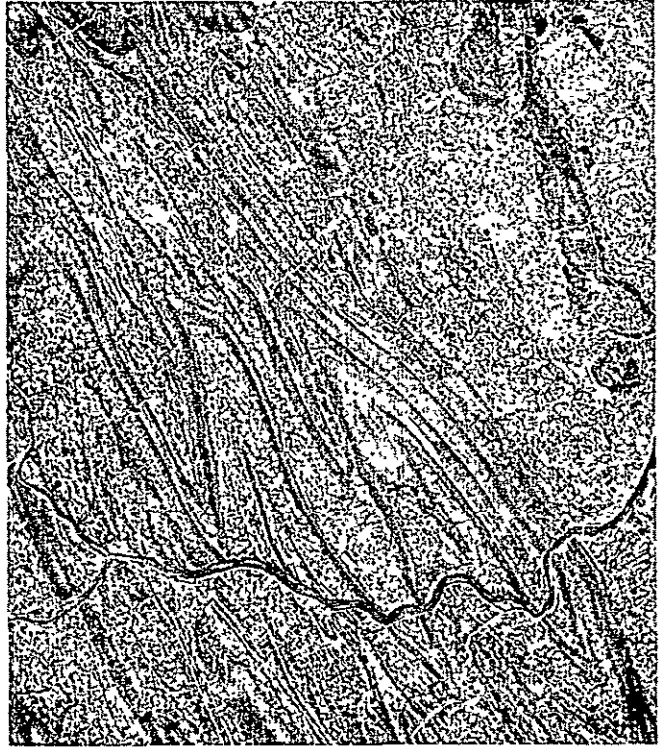
Figure 8: Summer ERTS scene in Channel 5.  
(Scene 1350-15190, 8 July 1973.)

Figure 7: Spring ERTS scene in Channel 5.  
(Scene 1260-15195, 9 April 1973.)

Figure 9: Fall ERTS scene in Channel 5.  
(Scene 1440-15172, 6 October 1973.)

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Figures 10 through 13: Seasonal ERTS scenes in Channel 7.

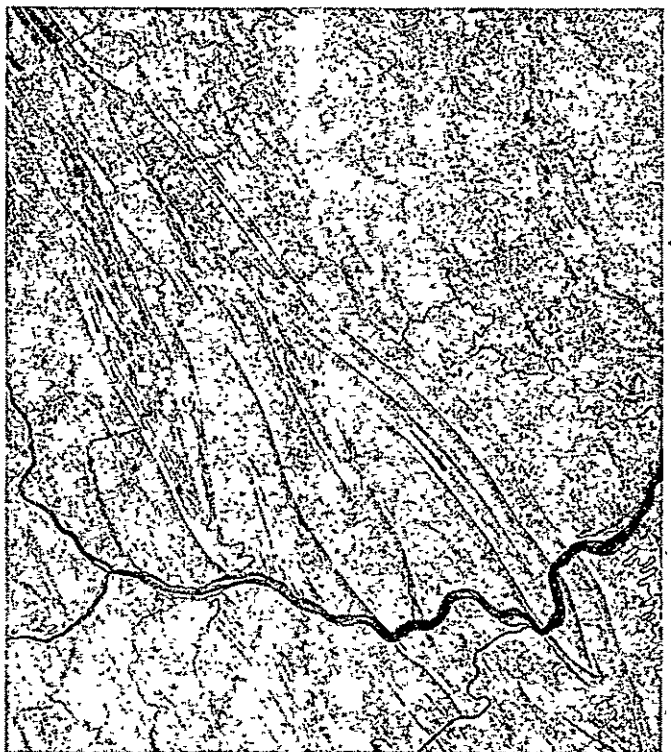
Figure 10: Winter ERTS scene in Channel 7.  
(Scene 1170-15191, 9 January 1973.)

Figure 12: Summer ERTS scene in Channel 7.  
(Scene 1350-15190, 8 July 1973.)

Note the gypsy moth damage evident in this scene (grey areas on the ridge in the right center and to the upper right in the scene). This damage is far more evident on this Channel 7 image than on the Channel 5 image (Figure 8).

Figure 11: Spring ERTS scene in Channel 7.  
(Scene 1260-15195, 9 April 1973.)

Figure 13: Fall ERTS scene in Channel 7.  
(Scene 1440-15172, 6 October 1973.)



the use of band seven, it is possible to delineate water, cities, and strip mines.

#### LAND USE ANALYSIS FROM SELECTED ERTS SCENES

ERTS scenes covering the southeastern portion of Pennsylvania were selected for study because that is where most of the state's agriculture is located. This area also has a wide variety of land uses, including agriculture, forest, urban, residential and strip mines, and is typical of northeastern Pennsylvania agriculture. Another reason for selecting this area is the complexity of the agricultural pattern. The fields are small, often less than 10 acres, and often laid out according to the contours of the terrain. Hence, the fields are usually not square, but curved in nature. This is further complicated by the practice of strip cropping, where on a particular slope crops are planted in alternating narrow strips of sod crops and row crops. This practice tends to reduce erosional losses, but greatly complicates the agricultural field pattern.

For the analysis of this area (shown on the location map of Figure 5), the following ERTS scenes, in bands 5 and 7, were selected:

9 Jan 73, 1170-15191 (Figures 6 and 10)

9 Apr 73, 1260-15195 (Figures 7 and 11)

8 Jul 73, 1350-15190 (Figures 8 and 12)

6 Oct 73, 1440-15172 (Figures 9 and 13)

From a perusal of these images, it is relatively easy to delineate the agricultural areas, but almost impossible to delineate individual fields.

Additional information can be obtained from a temporal analysis. For example, the January imagery (Figures 6 and 10) is very useful for delineation of the ridges and other geologic features. Most of the forested, nonagricultural areas show up as dark toned in band five (Figure 6). The low sun angle tends to enhance the differences in relief. In the April imagery (Figures 7 and 11), there are very few tonal differences, either within an image or among images. Most of the ridges are covered with deciduous trees and the agricultural crops are not actively growing at this time. Hence, there is a general lack of vegetative response at this time of year. However, southern portions of an ERTS springtime image often shows a response differing from that of the northern portions, indicating the progression of vegetative response from south to north.

The July imagery (Figures 8 and 12) shows the greatest differences in band response of the four scene dates. In band five (Figure 8) the forested ridges are dark and the agricultural valleys are light. The reverse is true in band seven (Figure 12). An exception to this is where some portions of the ridges have a dark tone in band seven. These are forested areas that are infested with the gypsy moth and, hence, their reflectivity in this band is reduced. These areas are not to be confused with the very dark strip mine areas. Strip mines are observable in all scene dates, whereas the gypsy moth infestation can only be seen in the July data.

Considerable tonal differences are also observed in the October imagery (Figures 9 and 13), although these are not as great as in the July imagery. The deciduous trees are just starting to undergo change in color and most of the agricultural crops are beyond their most active growth period. The response from vegetation, therefore, would be reduced when compared to the July date. It should also be noted that the gypsy moth infestation is not detectable at this time, illustrating well the importance of temporal data when observing a dynamically changing environment such as vegetation.

#### DETAILED ANALYSIS OF A SELECTED AREA WITHIN AN ERTS SCENE

The complex nature of the agricultural patterns in Pennsylvania usually requires detailed analysis of selected areas within an ERTS scene. To illustrate this type of analysis, a study site was selected in the north central portion of the July 8, 1973 scene shown in Figures 8 and 12 (ERTS Scene 1350-15190). Ground truth available for this area included:

1. USGS 7-1/2 minute topographic maps;
2. an October 1969 ASCS 1:63,000 photomosaic;
3. ASCS 1969 aerial photographic prints at a scale of 1:12,000;
4. aerial photographs at scales from 1:6000 to 1:120,000, flown in December of 1973 and February and April of 1974, as color positive, color IR, and black and white multispectral transparencies; and
5. high altitude aerial photographs at scales from 1:130,000 to 1:450,000, flown in February of 1974, as color, color IR, and black and white multispectral transparencies.

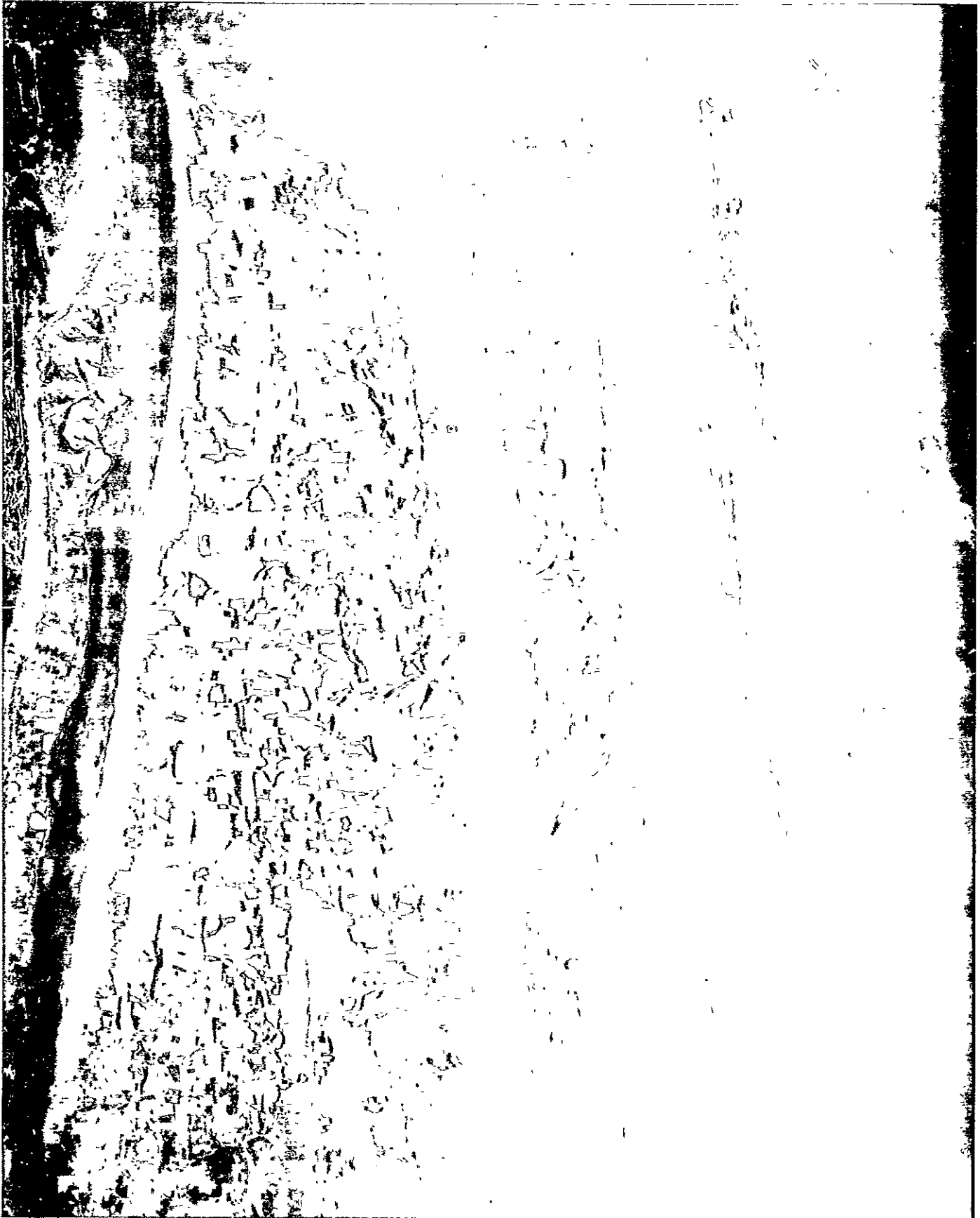
The study site, encompassing an area of approximately 1225 sq km (35 x 35 km) is delineated on the map in Figure 5. Figure 14 shows a U2 photograph of approximately 520 sq km of the study site. The area covered by this photograph is also shown on Figure 5.

In an effort to delineate land use classes, various photographic products were made. These included enlargements to scales ranging from 1:500,000 to 1:140,000, using 70 mm negatives from the four bands of the ERTS scene. Although one could delineate small streams, rivers, strip mines, forested ridges, and agricultural areas on these enlargements, it was not possible to discern individual agricultural fields. A positive-negative approach was then attempted, superimposing a negative transparency from band 5 with a positive transparency from band 6. This combination was enlarged to 1:140,000. However, delineations within agricultural areas were still not possible.

In study areas such as this, therefore, where much greater resolution is required, it is necessary to use digital tape data. For the following study, 500 scan lines were selected with 690 elements in each line, for a total of 345,000 pixels. The width of the scan line is approximately 79.1 meters and the width of each element is 57.3 meters. Thus, each pixel is approximately 0.45 hectares (1.1 acres) in size.

Figure 14: U2 photography of a portion of the study site shown in Figure 15.. (From 9 x 9 inch color IR scene 6059, sensor 23, mission 74-016, 5 February 1974.)





Using an unsupervised classification procedure (the ORSER DCLUS program--see ORSER-SSEL Technical Report 16-74 for program descriptions), the following categories were delineated: (1) forest land with a northern aspect; (2) forest land with a southern aspect; (3) valley trees; (4) wheat; (5) corn; (6) alfalfa, grass, pasture; (7) disturbed land; (8) built-up areas; (9) strip mines; and (10) water. The digital response of these categories within each band or channel is given graphically in Figures 15-17.

These responses were used to produce a digital map (Figure 18) with the above ten land use categories delineated at a scale of approximately 1:20,000. In general, the classification was accurate. However, some misclassification did occur which was the result of the complex nature of the land use, where several types of land use occur within a given pixel. There were also some instances where signatures were derived and it was not possible to determine the category into which the signature should be placed.

Another problem with the digital approach is that the response from a similar target can vary within a scene or can vary from one day to the next. This is illustrated when one compares the response of the targets in Figure 19 with those of Figures 16 and 17. In cropland, these differences could be due to physiological differences, such as variations in maturity. Even with due consideration to these types of problems, digital processing is still necessary in an area such as Pennsylvania. This is the only system that has a great enough resolution to delineate between fields. The speed of the analysis and the ability to obtain summaries of the areal coverage of the various categories are also decided advantages of this approach.

Land use delineations can also be made using an interactive analysis system such as the General Electric Image 100 (see ORSER-SSEL Technical Reports 4-75 & 15-75). This system utilizes digital tapes and displays the classification results on a color cathode ray tube. The main advantage of this system is its speed. It has some disadvantages, however. One is that the size of the ERTS scene which is displayed is limited by the size of the cathode ray tube. Also, the categories are determined by looking at a small number of representative pixels, rather than a large number, as is done with the digital computer. Hence, the statistical validity of the signature may be in question. Finally, the output products at present are only in the form of photographs of the cathode ray tube -- not the most usable type of output product. This system is constantly being modified and it is anticipated that these problems will be alleviated.

The effectiveness of any of these analyses systems would be greatly enhanced by the use of temporal data. In such investigations, it would be desirable to merge the digital data from various scene dates onto a single data file. Thus, for a given pixel there may be 8, 12, 16 . . . channels of data, rather than the four channels of a single scene. Spatial corrections and alignment of the pixels would be necessary, but once this is accomplished considerably more information would be available to the user.

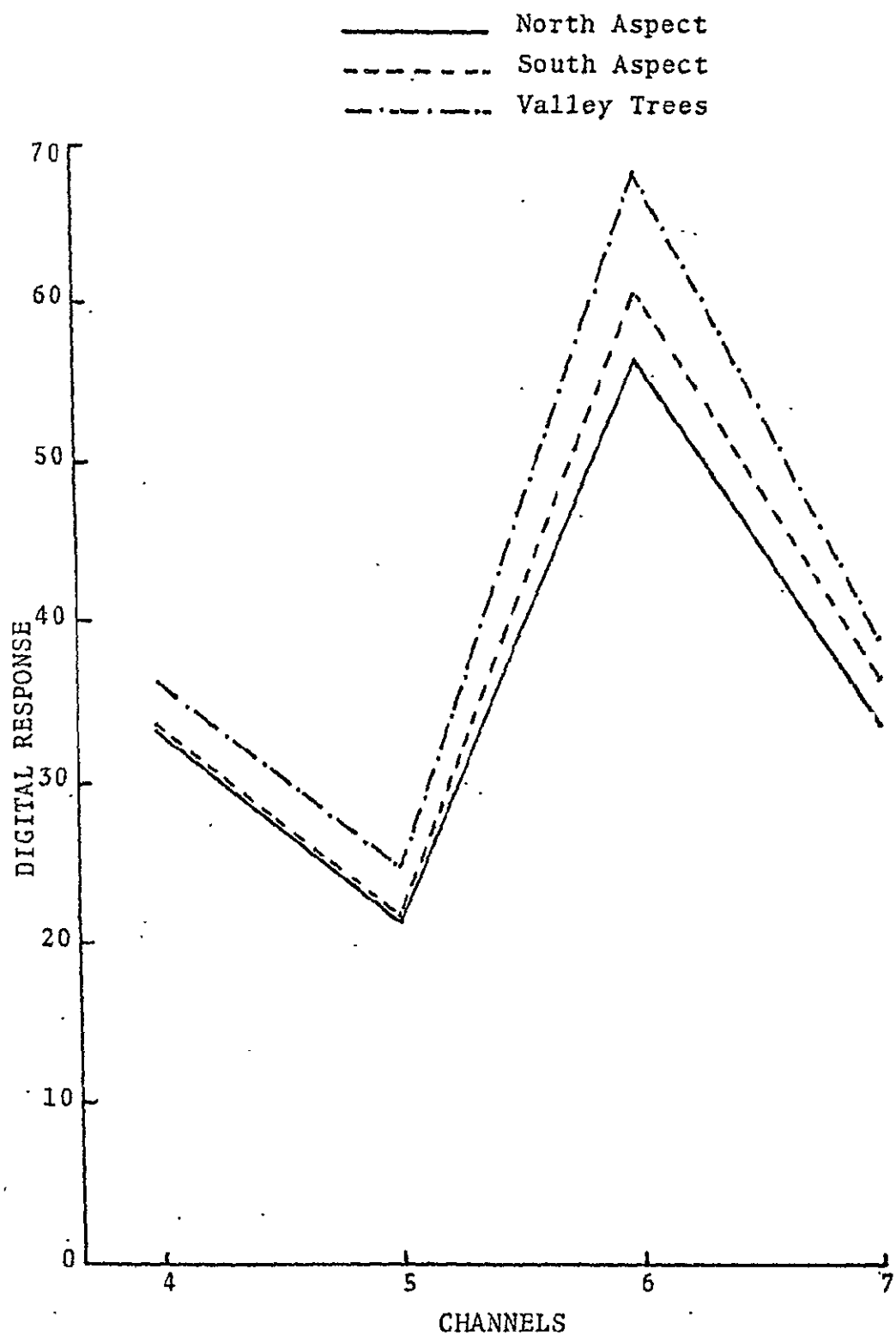


Figure 15: Digital response of forest lands.

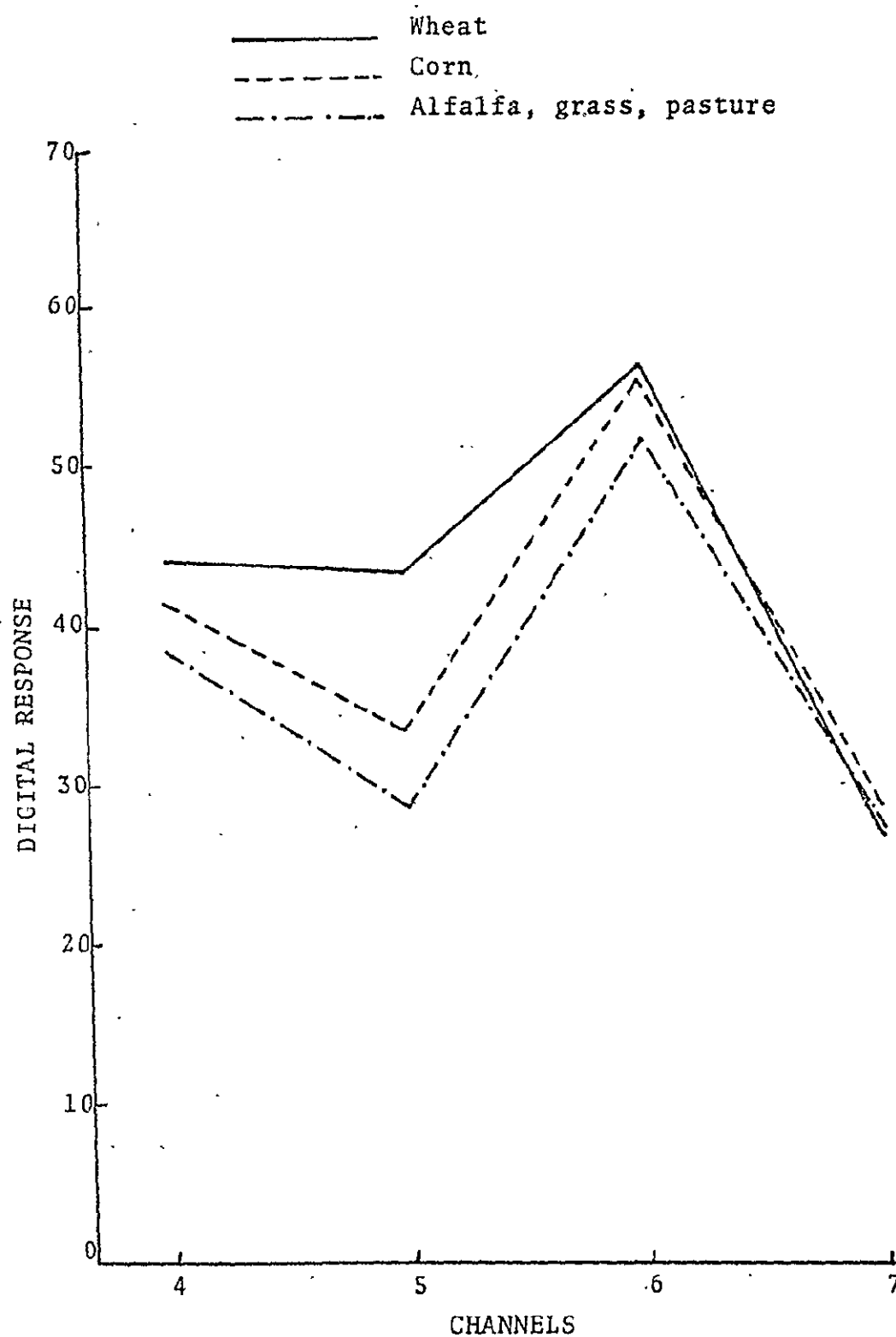


Figure 16: Digital response of croplands.

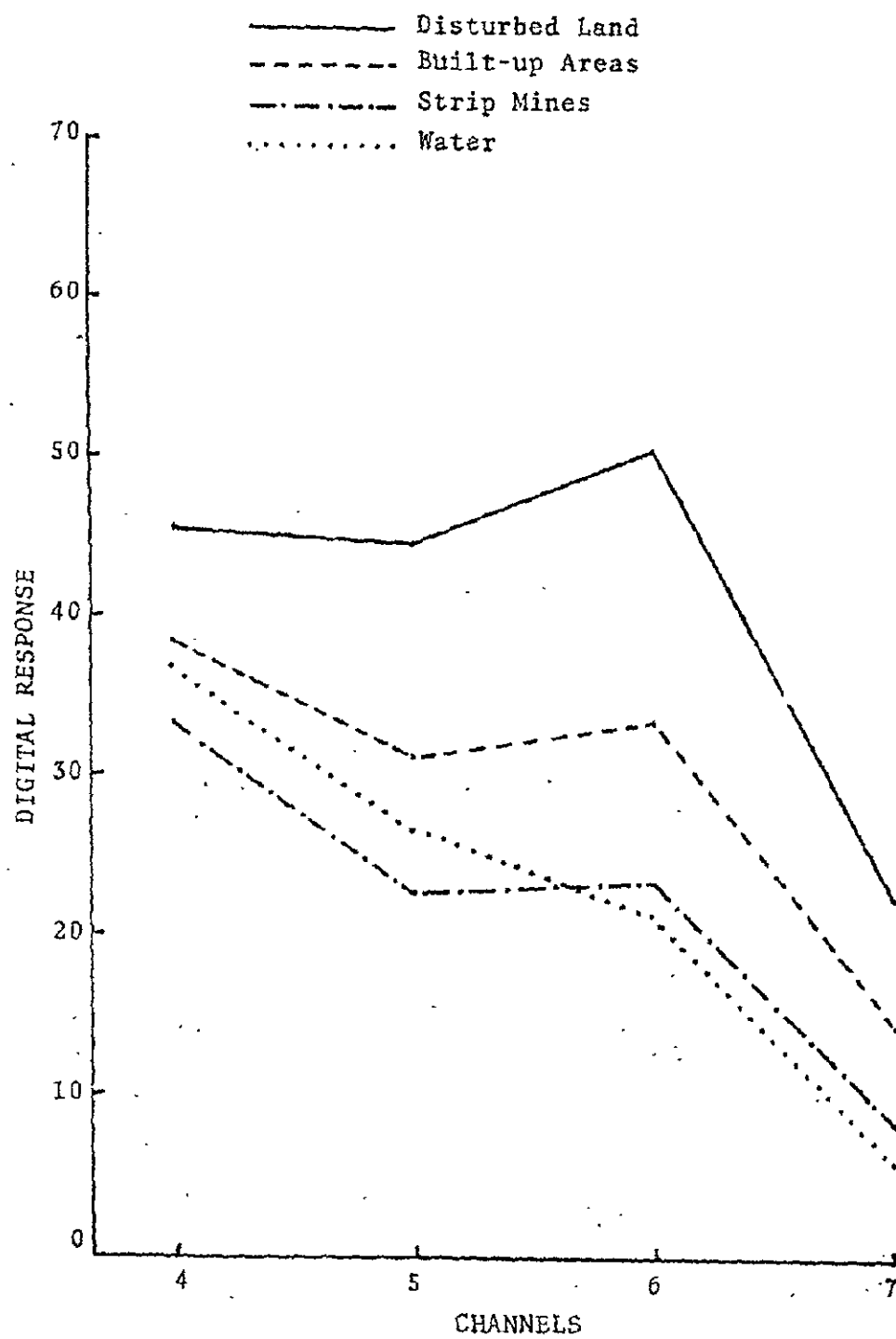
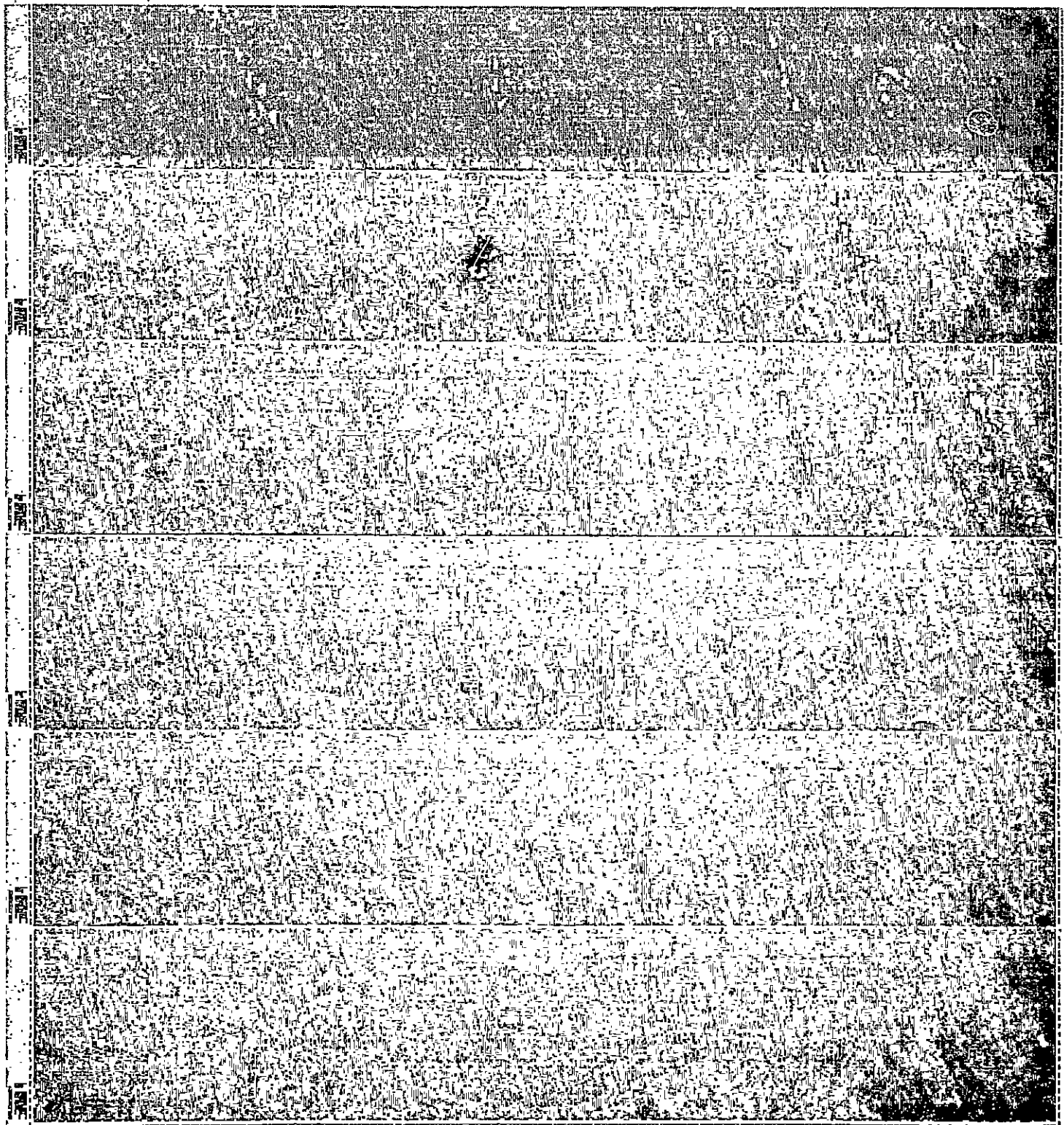


Figure 17: Digital response of non-vegetated areas.

Figure 18: Photographic reduction of a land use classification map of the study site generated by an unsupervised classification algorithm.

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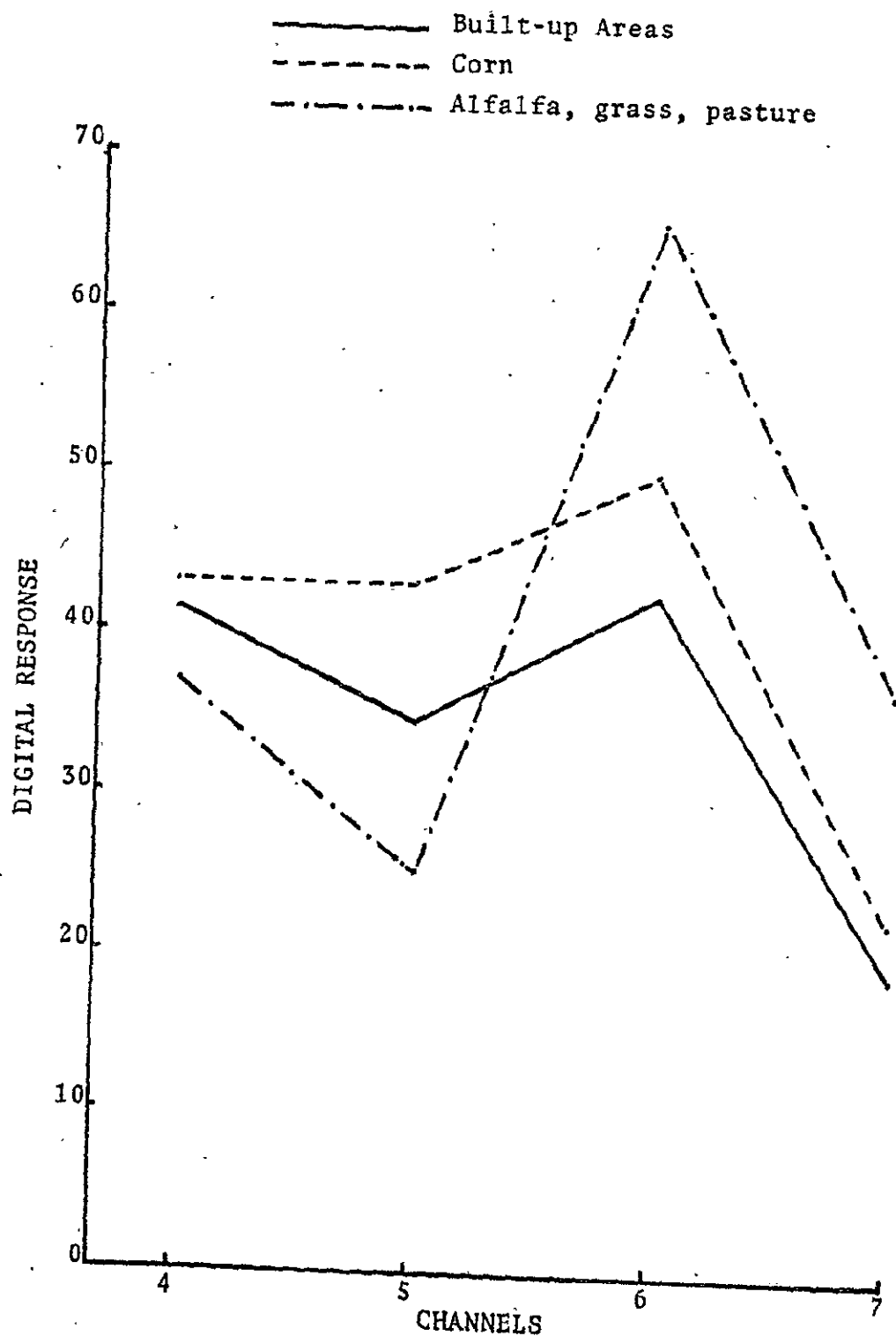


Figure 19: Digital response one day prior to, and approximately 75 miles southeast of, the test site represented in Figures 16 and 17. (Data obtained from a similar study done on scene 1349-15132 in the area of Norristown, Pennsylvania.)



### CONCLUSIONS

The interpretation of agricultural land-use from an area such as Pennsylvania is difficult. Probably, the only way in which it can be adequately accomplished is by the use of a hybrid approach (see ORSER-SSEL Technical Report 13-73). This would involve the interaction of the computer analyst with the photointerpreter, using various types of ground truth to compare with the computer output. Such analyses would be greatly facilitated if digital processing could be interfaced with an interactive analysis system using merged data.

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The Pennsylvania State University

